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Performance measurement in a quality management system

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Abstract Quality management system implementation has become a must for construction companies in some countries to be able to enter tenders. One of the most common quality standards is the ISO 9000 quality management standard and many companies seek ISO 9000 certification in today's highly competitive market. However, in getting this certification, most companies face difficulties, such as the high amount of paperwork, improper documentation, poor communication among employees and project participants, and low employee morale as a result of lack of motivation. In this study, a web-based office automation system was developed. Web facilities and the database management capabilities of Microsoft Visual Studio 2008 were applied to create a data warehouse that was aimed to reduce paperwork, create a proper documentation system, improve communication, and calculate employee performances, in order to create a motivation system for company personnel. Short-term feedback of the practical implementation of the system demonstrated its practicality and advantages, and the positive view of the managers. Also, it is anticipated that long-term feedbacks would also prove its appropriateness and ease of use.

1. Introduction

Quality Management System (QMS) certification has become a must in today's highly competitive construction market. One of the most common methods of quality management system application to a construction company is ISO 9000 certification. While the reason for many companies wishing to achieve a quality management certificate, like ISO 9000, is only for eligibility to enter tenders, some other companies seek for ISO certification to benefit genuinely from its numerous advantages. However, construction companies face a number of difficulties in the certification process, including an increase in paperwork, an improper documentation system and poor communication among personnel. As a result, these may cause re-working, as mentioned by Alshawi and Ingirige [1], low worker interest in applying new working methods [2–5], and low employee morale and motivation. These problems make the certification process arduous and thus some companies might even give up.

The aforementioned problems will, on the other hand, influence company performance. Literature shows a considerable increase in the field of supply chain performance and its effects on company performance [6–19], and company performance management and measurement [20–25]. The majority of researchers used structural equation modeling and, through the development of a number of hypotheses, tried to prove or reject them based on a survey among different experts. However, research on performance quantification is relatively scarce, and less attention has been paid to employee performance.

A number of office automation systems are currently being used, such as Autodesk Constructware, Business Collaborator, and e.Build.ca. Autodesk Constructware creates a centralized database of all project documents, which can be accessed by all project participants, and which is capable of managing documents, design, bidding, costs, construction and operations. Business Collaborator facilitates collaboration across teams, automates processes and enables access to project information. It is only aimed to automate traditional paper-based processes to improve response times, reduce errors and cut costs. The Collaborative Business Platform from e.Build.ca is an online collaboration and project management tool designed for the planning, design and implementation of construction projects. However, these programs were not designed for measuring employee performance, or provide a decision tool for managers

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to monitor employees, develop an Organizational Breakdown Structure (OBS) with appropriate lines of communications for ease and inform recipients by messages on his mobile phone to save time and enhance performance.

This research fills this gap by developing a system to measure the performance of personnel and subsequently apply the obtained performance factor to motivate and appreciate the personnel, which in-turn affects employee performance and, consequently, company performance.

The objectives of the present research study were to overcome QMS deployment problems and create a decision tool for company managers to track employee performances. The data warehousing technique and soft computing methods were applied to develop a system called Performance Management Support System (PMSS). PMSS is a web-based office automation system that measures the performance of employees based on three management factors of time, cost and quality. Each of these indexes could provide useful information for managers [26] and are emphasized by many researchers [27–29]. The measured performances can further affect their standing in the company and also their salaries. This is highly effective on the motivation of personnel, as a result, creating a competitive environment among personnel and encouraging them to undertake their responsibilities in the shortest time with the lowest costs and at the highest quality level. Thus it overcomes QMS deployment difficulties and ultimately imposes continuous improvement. PMSS is generally designed and developed for every organization type; however, due to the more complex nature and uniqueness of construction projects and construction companies [30], the practicality of the developed system was checked through evaluations with experienced general managers of some construction companies and ISO certification agencies. Time saving, cost reduction, less paperwork, easier communication and more efficient documentation were affirmed to be the most important advantages of PMSS. The feedbacks approved the appropriateness and applicability of the system in the construction sector.

2. Literature review

2.1. Quality management

Quality management is a critical component in the successful management of construction projects. ISO 9000 certification is the most successful quality management system for many construction companies. However many researchers (e.g., [2–5, 31–37]) emphasized the difficulties of the certification process. These include an increase in paperwork, an improper documentation system and poor communication among personnel. Soft computing and Internet technology is believed to be a good solution for such problems [38,39].

Many attempts have been devoted to solving such problems and inconsistencies in the construction industry. Lam and Ng [2] used an Internet-facilitated quality management environment that aims to examine the potential of applying the web-based techniques to collect, manage, access and distribute quality-related data at the construction project level. Kim et al. [35] developed a Personal Digital Assistant (PDA) which used a wireless web-integrated system, and which was intended to perform quality inspection and the defect management of apartment housing projects. The ISO 9000 Quality Management Information System (QMIS), developed by Chin et al. [32], was proposed to integrate scheduling with the quality system process. However, lack of enthusiasm still exists among workers and employees. They believe that the certification process and application of a quality standard will control their performance, and will act as a controller limiting them [40].

Thus, an Integrated Information System can help overcome quality management system deployment difficulties in a construction company.

2.2. Performance management

In today's highly competitive market, traditional organizational management methods cannot be considered appropriate strategies. Recent developments in database management systems, Internet technology and office automation systems encourage managers to apply these methods to their company in order to survive and compete with their competitors. Performance measurement is one of the most important decision tools for managers.

A performance measurement system can be defined as a set of metrics used to quantify both the efficiency and effectiveness of actions [41,42]. Performance measurement methods are attractive to researchers, as stated by Phusavat et al. [43,44]. ISO 9001:2008 clearly specifies performance measurement as part of its requirement no. 8. Performance measurement helps to bring more scientific analysis into a decision-making process. It underlines the change towards management by information and knowledge, instead of primarily relying on experiences and judgment [43].

Since 1980s, the focus of performance measures shifted from purely financial factors to a combination of financial and non-financial ones. The factors affecting performance measurement in different research studies are based on one, or a combination of some criteria like finance, operations, quality, safety, personnel and customer satisfaction. Methods like the balanced scorecard, the performance pyramid, the performance measurement questionnaire, the results and determinants framework, the performance prism, the economic value added, and the Skandia navigator have recently been used [13,45–57].

Ho [21] states that performance refers to the achievements, in quality and quantity, of an individual or group work. Employees are critical components of business success [21] and their performances directly influence company performance [58]. Thus effective strategies to motivate and enhance employee competency are of urgent need for companies. Literature does not show much work on employee performance. Medlin and Green [59] examined the relationship between the constructs of employee engagement and employee optimism, as a means to improve employee performance. Kuo et al. [25] researched using productivity and attendance as evaluation criteria for employee performance. Tarng and Liu [60] developed a document management system that creates microfilm from all documents, which in turn could be used to evaluate employee performance.

Lack of proper links between information systems and performance measurement systems is highlighted in different studies [47,54]. They stated that advances in information technology, such as data warehousing and web-based technologies, can support performance measurement systems to achieve enhanced efficiency and effectiveness. Laitinen [61] emphasized the role of management information systems in delivering information to managers. He points out that a CEO spends, on average, 23% of total working time on getting information. He continues that, together with informing and reviewing information, information-handling occupies, on average, 51% of a total

working day. The role of information systems and database systems on performance measurement was discussed in a study conducted by Phusavat et al. [43].

It can be concluded that the importance of company performance and the factors affecting it are stressed in different studies. However, a quantitative employee performance measurement method rarely exists. Thus it is believed that it is necessary to conduct a more comprehensive study on employee performance. Considering an Integrated Performance Measurement System (IPMS), a quantitative method using a data warehousing technique was, thus, developed, which calculates employee performance by using three classic project progress issues, such as cost, time and quality [62]. These metrics were emphasized in a number of research studies, to be the most important measurement factors of performance [63–67].

Thus employee performance measurement and motivation of personnel could create a competitive environment among them, which in-turn would help managers to control their subordinates, together with enhancing company performance.

2.3. Data warehousing

Enterprises are increasingly turning to software systems to seek support for enterprise performance measures [68]. Companies need to have proper information systems and database management systems to capture and keep different information, which are their most valuable resources.

Successful support of managerial decision-making is critically dependent upon the availability of integrated, high quality information, organized and presented in a timely and easily understood manner [69]. Despite the growing need for more information, every day organizations create billions of bytes of data about all aspects of their business. It is estimated that only a small fraction of the data that are captured, processed and stored within the company is actually ever made available to executives and decision makers [70]. The concept of a Data Warehouse (DW) is part of the response by IT to meet this need, as pointed out by Golnabi et al. [71]. A functional DW organizes and stores all available data needed for informational and analytical processing over a historical time perspective [72], and provides decision makers with consistent, timely, reliable and accessible data without a negative impact on the operational systems from which the data is extracted [68,73].

DW by itself does not create value. The value comes from the use of its data in other applications. Another fact is that a DW is not a ready package to be bought and used by a company; instead, it should be specifically designed to meet company needs. This idea encourages companies to develop their own DW and appropriate computer applications to solve and overcome their difficulties, and take the maximum benefit out of data warehousing capabilities.

Jarke et al. [73] define a DW as a structured extensible environment designed for the analysis of non-volatile data, logically and physically transformed from multiple source applications to align with business structure terms, and summarized for quick analysis. An important concept of a DW is that its data comes from one or more operational applications, manipulated into a common format for the warehouse, and inserted into the warehouse with any necessary calculations or additional appended data. Then, the data are loaded into appropriate reference tables for efficient query performance, analysis, reporting or data mining by the user, through different available tools, such as web applications or crystal reports. A relevant data mining tool is On-Line Analytical Processing (OLAP), which provides a service for accessing, viewing and analyzing large volumes of data with high flexibility and performance. The essential characteristic of OLAP is that it enables a numerical and statistical analysis of data organized in a multi-dimension [72,74].

DW typically uses multidimensional, as well as relational, storage structures [68]. The multidimensional structure physically stores the data in array-like structures that are similar to a data cube. In the relational structure, the data are stored in a relational database using a special schema (star or snowflake) instead of a traditional design. The developed system in the present study uses a relational structure, considering star schema.

Multidimensional OLAP is used for a multidimensional database system, and a relational OLAP for a relational database system. The relational OLAP is designed to remove the technical constraints of traditional data access methods, resulting in a faster response and ease of use [75].

A number of research studies on DW applications in the construction industry [76–80] show that it has considerable application potential. Historical data storage and access, data extraction from different internal and external data sources, data cleansing and analysis, and OLAP capability in report retrieving are main characteristics of data warehousing, which encouraged authors to consider it for the present system development.

Different departments exist in a construction company, and each of them has its own activities and work procedures. These departments may use their own Information Systems (IS). On the other hand, a company normally has several projects that could also have their own IS. These systems are considered as data marts for the main office data warehouse. A data mart is a subset of an organizational data store, usually oriented to a specific purpose. The developed system uses the data marts to calculate employee performances and provide different reports, using OLAP capabilities.

Thus, the data warehousing technique could be a proper solution for companies to develop integrated database management systems and decision tools.

3. Methodology and system development

The methodology was based on developing a web-based office automation system for performance measurement using a data warehousing technique. Considering the results of a literature survey, the system development took place in almost two years. Then consulting with some experts in both fields of management and IT, the primary pilot model was revised and the present system was developed and ready to be practically checked at the end of 2009.

The developed system consists of three major parts including databases, user interfaces and web applications. Microsoft Visual Studio 2008 was used to develop the main structure of the system. Microsoft Visual Studio is an Integrated Development Environment (IDE) from Microsoft, which can be used to develop console and graphical user interface applications along with web sites, web applications and web services [81]. The database of the system was created using the Microsoft SQL Server 2005, which is a Relational Database Management System (RDBMS). User interfaces and web pages of the system were designed and developed using ASP.NET which is used to build dynamic web sites, web applications and web services. C# (C Sharp) was used to connect database, user interfaces and web applications.

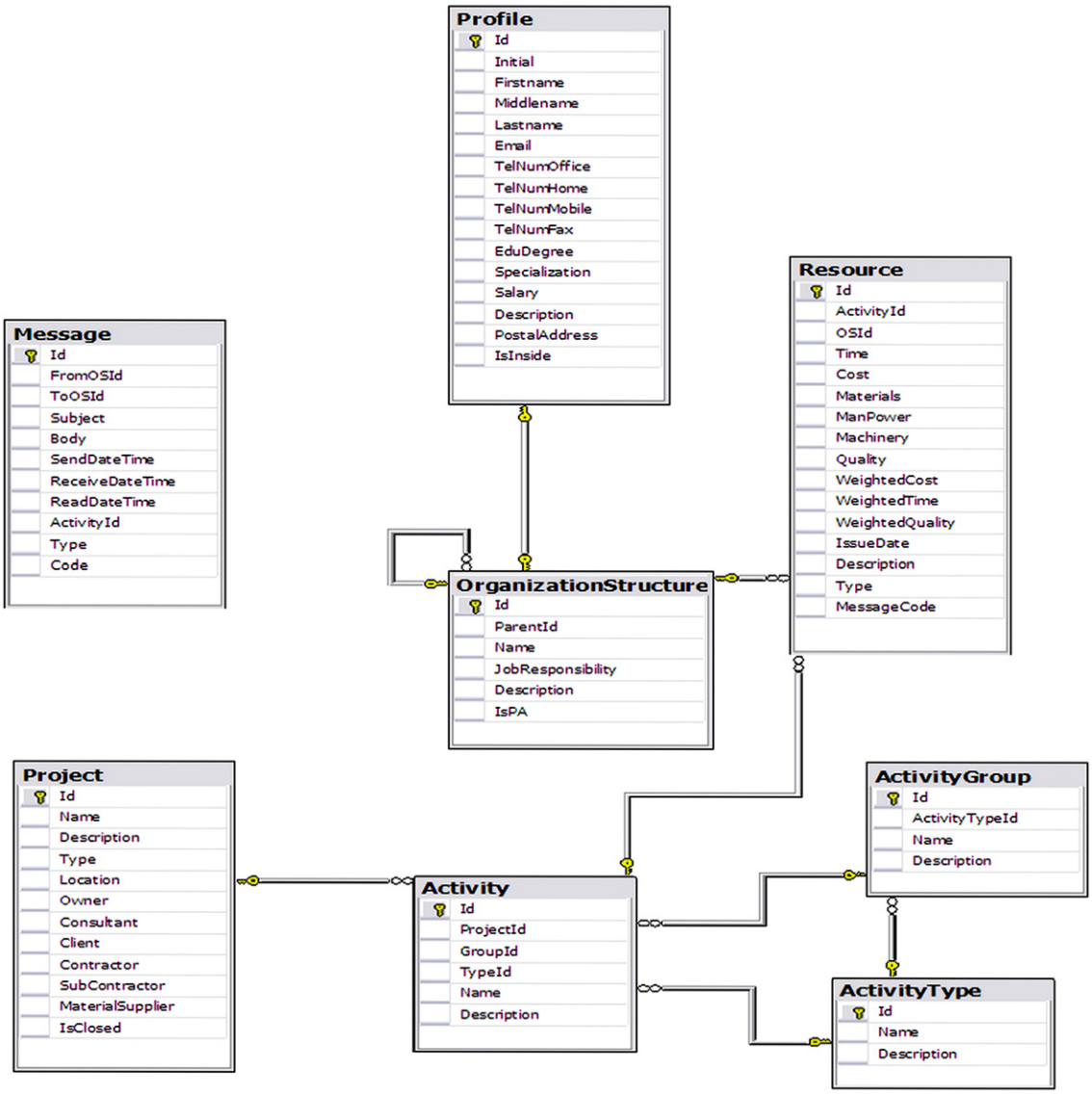

Figure 1: PMSS application diagram.

The OBS of the company will be developed by PMSS, and an employee will be assigned to each position in OBS. Personnel profiles and login accounts will then be created. The users can access the system through an authentication page. Different departments, projects, activities and their related data will then be defined. Users can use the message transfer mechanism of PMSS to send and receive work. The performance of each work undertaken is measured in three dimensions, namely time, cost and quality, and the performance of the employee will be calculated using the proposed formulas. A sample application diagram of PMSS is shown in Figure 1.

Various tables and databases are used to develop the system. An organization structure table is used to develop the OBS of the company. The departments and profiles of company employees are defined in the profile table. Projects and their related data are entered into the system through the tables, named as project, activity type, activity group, activity and resource. The heart of the system is the message table, which has the capability of transferring data, sending and receiving messages, measuring performances and storing all reports. The DW then uses the databases from different departments and projects to extract the necessary data to perform the required queries. The message table, shown in Figure 1, is not physically connected to other tables, since it can also be used by external users like clients, consultants, contractors and material suppliers, which are not placed in the organizational structure of the company. Therefore, it uses logical relations with other tables. The organization structure table has a "one to many" relation which means that each position in the OBS can have several positions under it.

Although the construction industry still prefers traditional hard copy documentation [1], PMSS aims to encourage construction companies to use IT and Internet facilities by its motivation system. The system will be installed on the company's main server and each user can login through the Internet. The user interfaces are as user friendly as possible, so that there is no need to be a professional computer user. The developed system facilitates the company to keep a copy of every single piece of work in its databases.

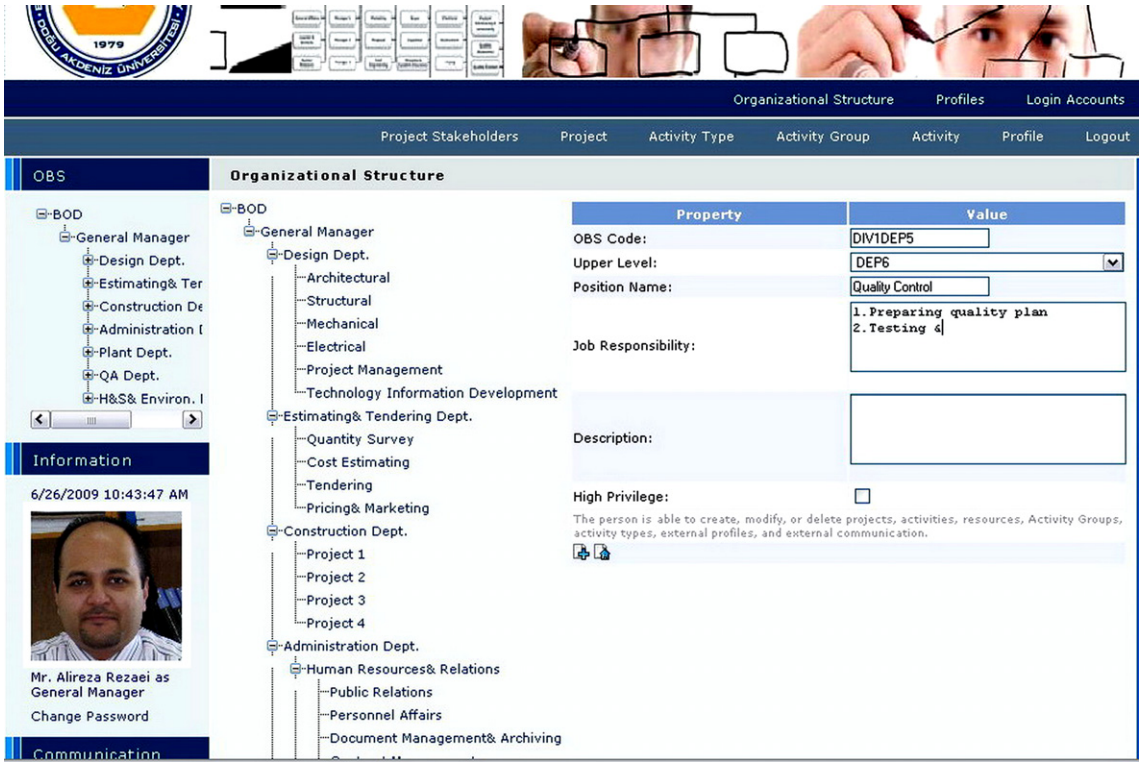

Figure 2: OBS creation in PMSS.

4. PMSS environment

PMSS can be accessed through the Internet by different web browsers, such as Mozilla Firefox, Microsoft Internet Explorer, Google Chrome, Opera, etc. Users of the system can be anyone who is assigned a username and a password. The system consists of the following parts.

4.1. OBS development

The setup and installation authority is given to the company's General Manager (GM) to define the company OBS. Among the different organizational structures [82], a functional organizational structure is used in PMSS, since most of the companies prefer it nowadays [83]. OBS creation has a dynamic structure which means that there is no limit to the number of horizontal and vertical levels; thus, each company can create its own OBS structure. One of the weaknesses of the functional structure is its low team member motivation [83]. PMSS, with its performance measurement feature and its motivation system, is deemed well to overcome this problem and make the functional structure more efficient. GM can delegate his authority to other personnel, such as head of the estimating and tendering department or head of the design department, to be able to create, define or modify projects, activities and resources. Other users have only access to the data for their work. A sample page of OBS creation is shown in Figure 2.

4.2. Project, activity and resource definition

Projects, activities and resources are specified by estimating and tendering department. After defining the projects and their related activities and resources, the system is ready to be implemented. Projects are defined to the system using the interface shown in Figure 3.

4.3. Message transfer system

All sending and receiving of work in PMSS are done through message transactions between users of the system, and through predefined lines of communication. Each user has a communication panel including "Negotiation", "Submitted" and "Performed" inboxes in his interface, which allows composing a message, negotiating over a received work, submitting work or performing work. Each message has two parties: a sender and a recipient. The sender of the message has alternatives of "Negotiate" on resources of the work or "Submit" it directly to the recipient. If the message came to the recipient through "Negotiate", he has the right to send back his opinion to the sender. This process can continue until both parties come to an agreement on the estimated resources required for the work.

If the work came from the sender through "Submit", then the recipient has no right to object to the estimated resources, just do the work and send it back. The resources can be time, money, machinery, material and manpower. The sender is capable of checking the workload of the recipient to fix the duration of the work.

The recipient of any message will be informed by a short message through his mobile phone as soon as receiving a message in his inbox. In a typical compose page, as shown in Figure 4, the head of the design department prepared a message to the head of the estimating and tendering department for estimating the price of a tower crane.

Once the work is completed by the recipient it will be sent back to the "performed" inbox of the original sender. Performed resource fields will be filled by the recipient, based on actual resources used. A sample of the performed message from the head of the estimating and tendering department to the head of the design department is shown in Figure 5.

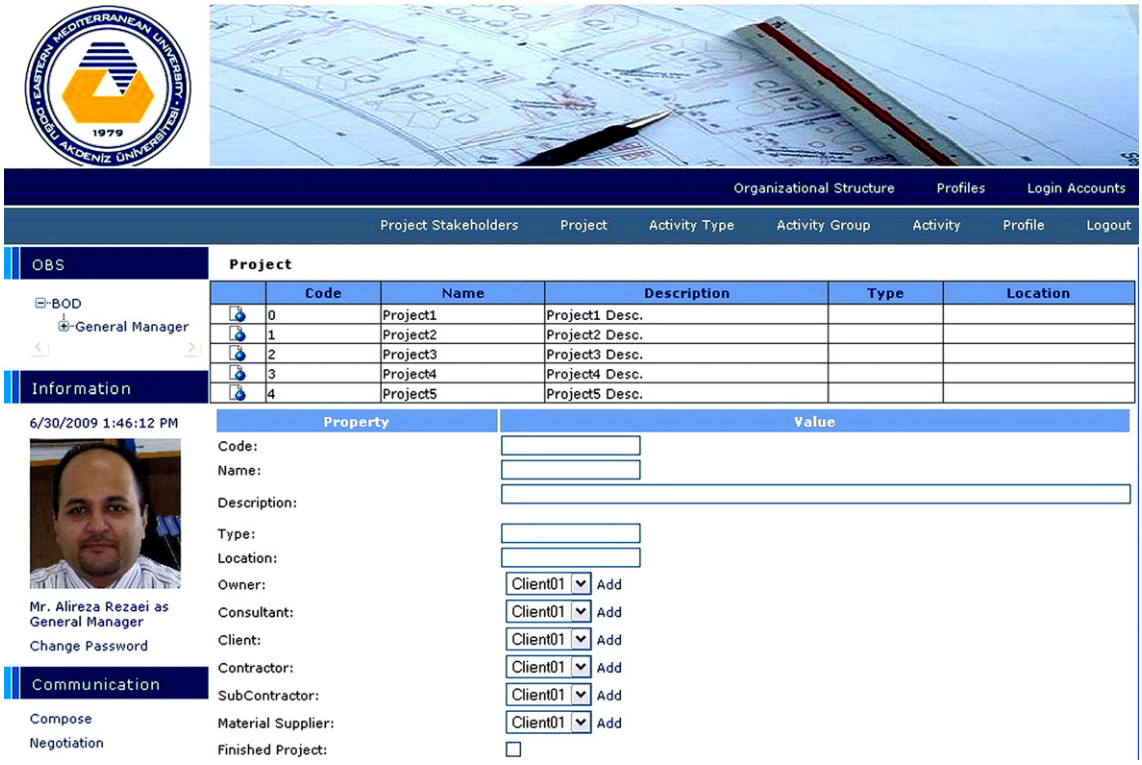

Figure 3: Project definition in PMSS.

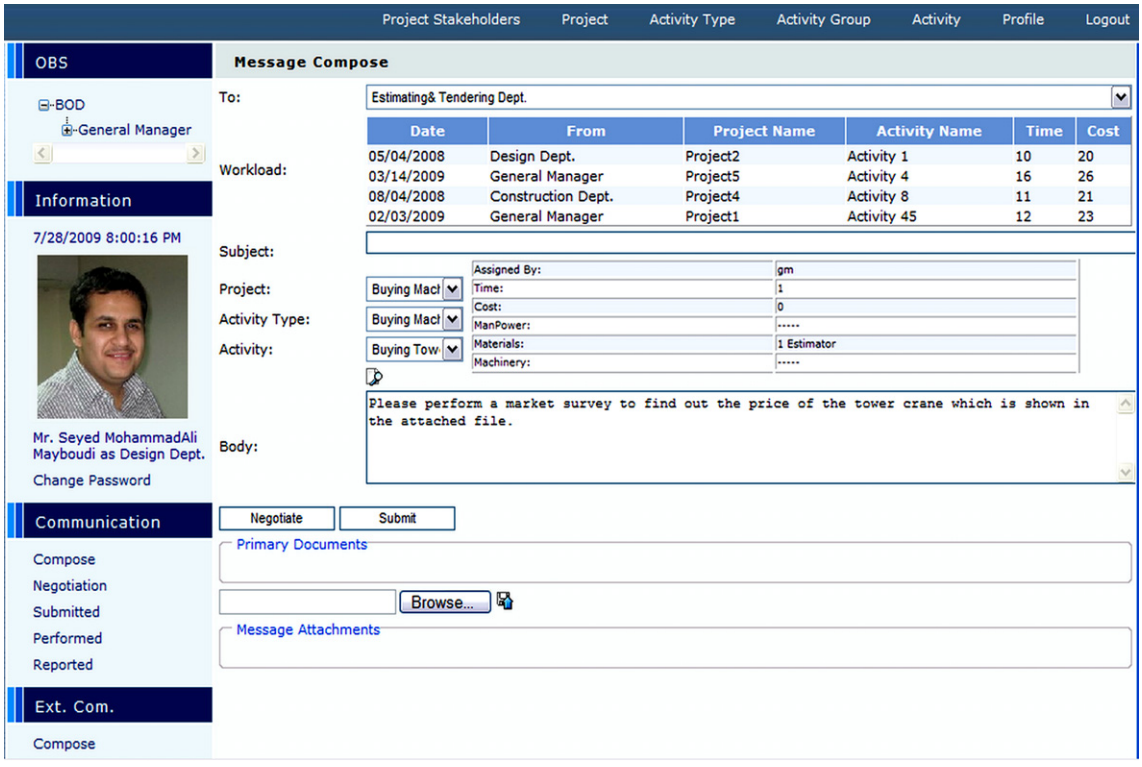

Figure 4: Compose page.

4.4. Performance factor calculation

Once the original sender receives a performed work, he will compare the estimated resources with the actual resources used, check the accuracy of the work and assign a grade for its quality. For every performed work, an Activity Performance Factor (APF) will automatically be calculated by the system using Eq. (1).

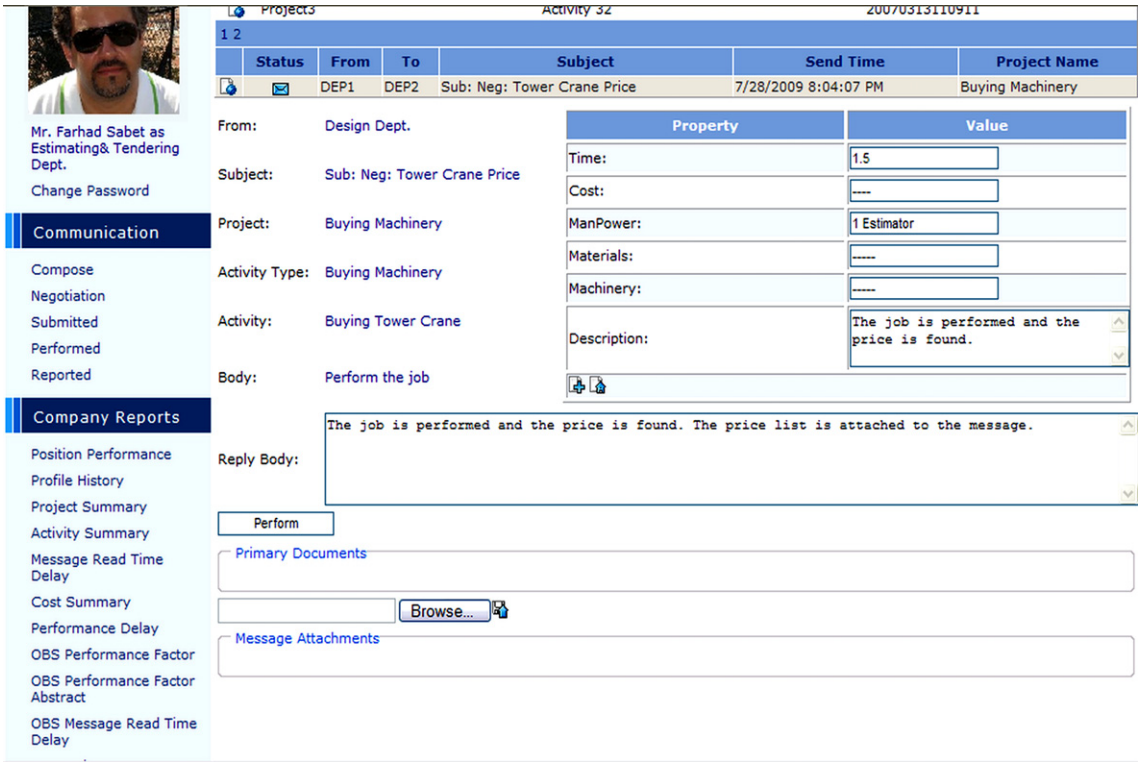

Figure 5: Performing message in PMSS.

Zegordi and Nahavandi's [84] simple definition of productivity is considered in Eq. (1). They defined productivity to be the ratio of output to input:

$$\text{APF} = \frac{T_{\text{est}}}{T_{\text{per}}} \times W_T + \frac{C_{\text{est}}}{C_{\text{per}}} \times W_C + \frac{Q_{\text{per}}}{Q_{\text{est}}} \times W_Q. \quad (1)$$

T_{est} and C_{est} are the estimated time and cost, respectively. Q_{est} of all activities is always assumed to be 100 and is not negotiated. Hoehn [85] and Neely et al. [57] pointed out the need to recognize different weights when measuring performance. W_T, W_C and W_Q represent the weighted factors of time, cost and quality, respectively. These factors are defined for every single activity, while specifying its resources by the estimating and tendering department. They explain the importance of each parameter. W_T, W_C and W_Q are considered as percentages and their sum is always equal to 100%.

T_{per} and C_{per} represent the actual time and cost used. Q_{per} is the quality grade and is assigned by the original sender on the basis of 0 to 100 measures. The subjectivity of Q_{per} is believed to be minimized by considering the number of mistakes/errors/deficiencies, the delay in reading messages, and percentage of work actually completed in T_{per} and C_{per}. One higher level authority will also be informed about the assigned Q_{per}. Q_{per} will be calculated by the following formula:

$$Q_{\text{per}} = \frac{D_{\text{est}}}{D_{\text{per}}} \times W_D + \frac{M_{\text{est}}}{M_{\text{per}}} \times W_M + \frac{PC_{\text{per}}}{PC_{\text{est}}} \times W_{PC}, \quad (2)$$

where D_{est} is acceptable delay for the company and is assigned by the estimating and tendering department, D_{per} is recipient delay time in reading the message, which is a percentage of D_{est}, M_{est} is the number of allowed mistakes/errors/deficiencies for a specific activity, and varies for different activities, which is assigned by the estimating and tendering department, M_{per} is the number of mistakes/errors/deficiencies occurred in a performed work, and PC_{per} is the percentage of work completed. PC_{est} is the estimated percentage of work completed within the assigned time (T_{est}) and by default is assumed to be 100%. W_D, W_M and W_{PC} are weighted factors of delay, mistakes/errors/deficiencies and percentage of work completed, respectively. W_D, W_M and W_{PC} are considered as percentages and defined by the estimating and tendering department for each activity, and their sum is always equal to 100%.

APF may be equal, less or more than 100%. If it is less than 100%, it means that the submitted work was performed at a lower level than expected. If it is equal to 100%, it means that it was performed as expected. If it is greater than 100%, it means that it was performed at a higher level than expected.

Every employee has a Performance Factor (PF) in the company. PF is updated, based on the OBS level, by using Eq. (3) or (4).

If the employee is at the lowest level in OBS, nobody gives him reports:

$$\text{PF} = \frac{\sum_1^n \text{APF}_i}{n} \times (1 - 0.005w), \quad (3)$$

where APF_i is the work performance obtained from a specific work and n is the number of total work performed so far, and w is the work experience of the employee in years. Other factors like the salary and education of an employee could also impact PF; however, only work experience was considered due to its higher importance.

If there are lower positions in OBS, giving reports to him:

$$\text{PF} = \frac{\frac{\sum_1^n \text{APF}_i}{n} \times (1 - 0.005w) + \frac{\sum_1^m \text{PF}_j}{m}}{2}, \quad (4)$$

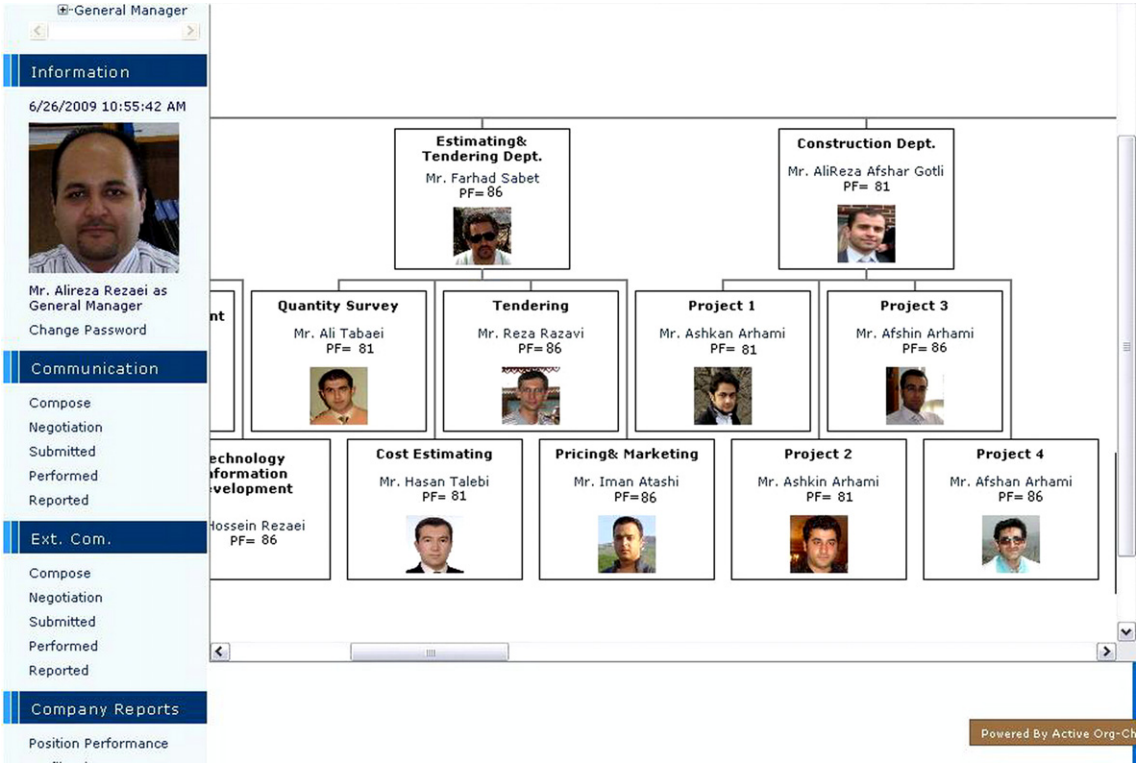

Figure 6: OBS with PFs report.

where PF_j is the performance factor of every lower level employee, and m is the number of lower level employees that so far give reports to him.

Obviously, an employee with a higher PF will have better standing in the company. Besides, depending on the policy of the company, these factors can be effective in determining an increment to the salary or other types of reward, since rewards will support the performance measurement system in being more effective [86,87]. Performance measurement can actually change the lives of people and organizations if implemented and used properly [88]. Thus, it is expected that such an application will strongly motivate employees to perform better.

4.5. PMSS reports

DW can extract the data from different departments and projects and, after cleansing, use them to provide various reports. It can also keep them as historical data for future use and reference. For instance, PFs can be shown on the OBS chart, as one of the reports of the system, as shown in Figure 6. The reports are online and updated automatically as any change occurs in the work and database.

Another report PMSS provides is the amount of delay each person caused in message reading. The difference between receiving and reading times of all received messages will be calculated and accumulated for each person. These delays could be shown both in tabular format and graphically, and could also be shown on the OBS chart. Cost reports, cash flow reports, activity reports, position reports and many other types of reports could also be retrieved based on need.

5. System evaluation

As stated by Laitinen et al. [89], IS can provide several benefits, such as improved productivity, innovation, market share and cost saving. The evaluation of an IS can be viewed as an exercise in determining its implementation success. Implementation success refers to different factors to be achieved; thus, evaluation is a multidimensional concept [90]. These factors vary according to different group (users, developers, managers) perspectives and the type of information system to be evaluated.

5.1. Primary system evaluation

Since the main focus of PMSS is construction companies, the pilot model was run with managers of some construction companies in Northern Cyprus and Iran, and ISO 9000 certification agencies in Iran.

The primary feedbacks attested that PMSS will provide a competitive environment among employees and thus can help companies to overcome the difficulties of quality management system implementation and ISO certification. Managers pointed out some benefits provided by PMSS including time saving, cost and expense reduction (as a result of decreased paperwork, reduction of administrative staff, decrease in office expenses, decrease in archiving space, etc.) accuracy increase, easier and faster performance measurement and calculation, and communication improvement. However, there were some recommendations for improving the practicality of the system, including:

- Allowing a time extension after initial submission of the work;
- Considering matrix OBS as well;
- Considering three other resources (material, manpower, and machinery) in performance calculation as separate parameters;
- Checking the recipient workload before submitting new work.

The feedbacks of the managers were then analyzed and most of them applied to the system. A time extension, after fixing the estimated resources, was added to the system, so that it was possible to bargain and change the resources after work submission. The matrix OBS could not be considered in the system since it is considered a limitation. Material, manpower and machinery were already considered to affect the cost, and their affects were included in the C_{est} and C_{per}. The recipient's existing workload consideration was also included, as shown in Figure 4. The modified PMSS was run again with the same managers, and they found it satisfactory and recommendable.

5.2. Final system evaluation

After final revision, the modified PMSS was practically installed in two construction companies in Iran at the end of 2009. After almost one month of training and debugging the system, it was implemented in those companies. The authors planned for two different feedbacks including short-term and long-term; the former from managers and the latter from both managers and employees. Short-term feedback was attained after one month of practical implementation. The summary of the short-term feedback from managers of two construction companies is as follows:

5.2.1. Cost reduction

One of the main advantages of PMSS was stated to be cost reduction. The managers believed that reducing the number of administrative personnel up to 50% would lead the company to cost savings including salaries, office space, furniture, indirect costs, food, etc. Another benefit of reducing the number of employees was stated to be making management more straightforward. It is obvious that managing a company with less numbers of employees is much easier. Cost saving and streamlining management would be more tangible for large companies.

5.2.2. Time saving

Another advantage was reported as being time saving. As declared by managers, the average delivery time for different work would be minimized by a message transfer system. It was also highlighted by ISO certification agencies that according to their experience with other IT systems, the spent administrative time would reduce between 40% and 60%.

5.2.3. Other benefits

Less paperwork, proper documentation and archiving and easier communication were also emphasized by managers, as a result of DW and IT usage. One manager expressed that archiving space, after ISO 9000 certification, was expanded to being 4 times bigger than before certification. They had to extend the buildings for administrative and archiving purposes. This imposed considerable expense on the company, including the need for new personnel, and also caused some difficulties in communication and data access. He claimed that using a system like PMSS would help companies prevent such extra expense and effort. On the other hand, an important issue for a manager is fast and easy access to necessary information, which can be achieved easily by utilizing a system like PMSS.

Managers also revealed that more accuracy would be attained by using PMSS. Almost 100% accuracy would be provided, compared with 15%–20% human errors faced by companies as stated by some managers.

5.2.4. Application difficulties

The only difficulty of PMSS application was believed to be the resistance of personnel. Clearly, every new system faces some resistance and adaptation difficulties. Management commitment and ability would encourage personnel to accept the new system and procedures.

Long-term feedback was expected to be obtained after longer time usage of PMSS. The authors expect to receive both managers and employees feedback after at least one year of PMSS practical implementation. As short-term feedback demonstrated the practicality and advantages of PMSS, together with the positive view of the managers, it is anticipated that long-term feedback will also prove its appropriateness and ease of use. Motivation cannot be measured yet, since it requires employee performance to be observed and evaluated after at least 6 months of PMSS implementation. However, with the effects of PFs on salaries and recognition, motivation will undoubtedly be imposed on employees. Therefore, PMSS advantages will be more documented with long-term feedback results.

6. Practical and managerial implications of PMSS

Performance measurement systems and information systems receive considerable attention nowadays; thus it is expected that PMSS, with both characteristics, will provide numerous and important advantages for its users. Although PMSS is still running in two construction companies, and long-term feedback has not yet been received, it is believed, and somehow proved by short-term feedback results, that some main practical and managerial implications of PMSS are:

- Positive effects on working behavior of employees and managers.
- Creation of a competitive environment among employees to perform their work in the shortest time, with the lowest cost, and to the highest quality level.
- Provision of a decision tool for managers to have quick and reliable access to employee performance, and to monitor the overall performance of their organization.
- Motivation of employees for better performance as a human resource management tool.
- To encourage companies seeking ISO 9000 certification or QMS deployment to start and continue the process, and overcome implementation difficulties.
- Reduction of costs through a reduction in the number of administrative personnel, office space and equipment, archiving space, etc.
- Assist organizations to make the best use of resources, such as time, cost, manpower, machinery and materials.

7. Conclusions

Companies seeking quality management system deployment, like ISO 9000 certification, face numerous discouraging difficulties. Major difficulties are paperwork, documentation, communication and lack of motivation.

Using a web-based office automation system, called Performance Management Support System (PMSS), managers would be promptly provided with accurate information about their business. PMSS reduces paperwork through appropriate IT utilization, decreases documentation problems by the use of a data warehouse, overcomes communication problems by using Internet and mobile phone facilities, and, finally, assists the

company in getting ISO certification as a part of its quality management system.

On the other hand, PMSS encourages employees to perform their jobs in the possible shortest time, with the lowest cost, and at the highest quality level to gain higher PFs. Obtaining higher PFs will provide a better standing of the employee in the company and contribute to earning more prerequisites.

PMSS only considers functional OBS and takes three indexes of time, cost and quality in performance calculations. Further studies can be conducted on other types of OBS and also separate consideration of three other resources in calculations.

References

[1] Alshawi, M. and Ingirige, B. "Web-enabled project management: an emerging paradigm in construction", *Automation in Construction*, 12, pp. 349–364 (2003).

[2] Lam, K.C. and Ng, S.T. "A cooperative Internet-facilitated quality management environment for construction", *Automation in Construction*, 15, pp. 1–11 (2006).

[3] Sroufe, R. and Curkovic, S. "An examination of ISO 9000: 2000 and supply chain quality assurance", *Journal of Operations Management*, 26, pp. 503–520 (2008).

[4] Ng, S.T. "Performance of engineering consultants in ISO 9000-based quality management systems implementation", *Engineering, Construction and Architectural Management*, 12(6), pp. 519–532 (2005).

[5] Pheng, L.S. and Wee, W. "Improving maintenance and reducing building defects through ISO 9000", *Journal of Quality in Maintenance Engineering*, 7(1), pp. 6–24 (2001).

[6] Allesina, S., Azzi, A., Battini, D. and Regattieri, A. "Performance measurement in supply chains: new network analysis and entropic indexes", *International Journal of Production Research*, 48(8), pp. 2297–2321 (2010).

[7] Pero, M., Rossi, T., Noe, C. and Sianesi, A. "An exploratory study of the relation between supply chain topological features and supply chain performance", *International Journal of Production Economics*, 123, pp. 266–278 (2010).

[8] Whicker, L., Bernon, M., Templar, S. and Mena, C. "Understanding the relationships between time and cost to improve supply chain performance", *International Journal of Production Economics*, 121, pp. 641–650 (2009).

[9] Kim, S.W. "An investigation on the direct and indirect effect of supply chain integration on firm performance", *International Journal of Production Economics*, 119, pp. 328–346 (2009).

[10] Craighead, C.W., Hult, G.T.M. and Ketchen Jr., D.J. "The effects of innovation-cost strategy, knowledge, and action in the supply chain on firm performance", *Journal of Operations Management*, 27, pp. 405–421 (2009).

[11] Yeung, A.C.L. "Strategic supply management, quality initiatives, and organizational performance", *Journal of Operations Management*, 26, pp. 490–502 (2008).

[12] Kojima, M., Nakashima, K. and Ohno, K. "Performance evaluation of SCM in JIT environment", *International Journal of Production Economics*, 115, pp. 439–443 (2008).

[13] Cousins, P.D., Lawson, B. and Squire, B. "Performance measurement in strategic buyer–supplier relationships—the mediating role of socialization mechanisms", *International Journal of Operations and Production Management*, 28(3), pp. 238–258 (2008).

[14] Sharif, A.M., Irani, Z. and Lloyd, D. "Information technology and performance management for build-to-order supply chains", *International Journal of Operations and Production Management*, 27(11), pp. 1235–1253 (2007).

[15] Carr, A.S. and Kaynak, H. "Communication methods, information sharing, supplier development and performance—an empirical study of their relationships", *International Journal of Operations and Production Management*, 27(4), pp. 346–370 (2007).

[16] Wong, W.P. and Wong, K.Y. "Supply chain performance measurement system using DEA modeling", *Industrial Management + Data Systems*, 107(3), pp. 361–381 (2007).

[17] Sepehri, M., Fayazbakhsh, K. and Ghasemzadeh, F. "A corporate supply optimizer with flow network", *Scientia Iranica, Transactions E: Industrial Engineering*, 17(1), pp. 70–83 (2010).

[18] Hosseini Baharanchi, S.R. "Investigation of the impact of supply chain integration on product innovation and quality", *Scientia Iranica, Transactions E: Industrial Engineering*, 16(1), pp. 81–89 (2009).

[19] Fazel Zarandi, M.H., Turksen, I.B., Moattar Hoseini, S.M., Bastani, S. and Mohebi, A. "A fuzzy intelligent information agent architecture for supply chains", *Scientia Iranica*, 15(5), pp. 623–636 (2008).

[20] Phusavat, K., Anussornnitisarn, P., Sujitwanit, S. and Kess, P. "Profile-based circumstances for productivity measurement", *Industrial Management + Data Systems*, 109(6), pp. 825–839 (2009).

[21] Ho, L.A. "What affects organizational performance? The linking of learning and knowledge management", *Industrial Management + Data Systems*, 108(9), pp. 1234–1254 (2008).

[22] Lin, C.Y. and Kuo, T.H. "The mediate effect of learning and knowledge on organizational performance", *Industrial Management + Data Systems*, 107(7), pp. 1066–1083 (2007).

[23] Rao, M.P. "A performance measurement system using a profit-linked multi-factor measurement model", *Industrial Management + Data Systems*, 106(3), pp. 362–379 (2006).

[24] Saad, G.H. "Strategic performance evaluation: descriptive and prescriptive analysis", *Industrial Management + Data Systems*, 101(8), pp. 390–399 (2001).

[25] Kuo, C.H., Dunn, K.D. and Randhawa, S.U. "A case study assessment of performance measurement in distribution centers", *Industrial Management + Data Systems*, 99(2), pp. 54–63 (1999).

[26] Arjomandi, K., Estekanchi, H. and Vafai, A. "Correlation between structural performance levels and damage indexes in steel frames subjected to earthquakes", *Scientia Iranica, Transactions A: Civil Engineering*, 16(2), pp. 147–155 (2009).

[27] Mirabi, M., Fatemi Ghomi, S.M.T. and Jolai, F. "A hybrid electromagnetism-like algorithm for supplier selection in make-to-order planning", *Scientia Iranica, Transactions E: Industrial Engineering*, 17(1), pp. 1–11 (2010).

[28] Seyedhoseini, S.M. and Hatefi, M.A. "Two-pillar risk management (TRPM): a generic project risk management process", *Scientia Iranica, Transactions E: Industrial Engineering*, 16(2), pp. 138–148 (2009).

[29] Jariri, F. and Zegordi, S.H. "Quality function deployment, value engineering and target costing, an integrated framework in design cost management: a mathematical programming approach", *Scientia Iranica*, 15(3), pp. 405–411 (2008).

[30] Azaron, A. and Modarres, M. "Project completion time in dynamic PERT networks with generating projects", *Scientia Iranica*, 14(1), pp. 56–63 (2007).

[31] Foster Jr., S.T. "Towards an understanding of supply chain quality management", *Journal of Operations Management*, 26, pp. 461–467 (2008).

[32] Chin, S., Kim, K. and Kim, Y. "A process-based quality management information system", *Automation in Construction*, 13, pp. 241–259 (2004).

[33] Turk, A.M. "ISO 9000 in construction: an examination of its application in Turkey", *Building and Environment*, 41(4), pp. 501–511 (2006).

[34] Motazed-Keyvani, R., Ghanbari-Parsa, A.R. and Kagaya, S. "ISO 9000 standards: perceptions and experiences in the UK construction industry", *Construction Management and Economics*, 17, pp. 107–119 (1999).

[35] Kim, Y.S., Oh, S.W., Cho, Y.K. and Seo, J.W. "A PDA and wireless web-integrated system for quality inspection and defect management of apartment housing projects", *Automation in Construction*, 17, pp. 163–179 (2008).

[36] Tam, V.W.Y. and Le, K.N. "Quality improvement in construction by using a Vandermonde interpolation technique", *International Journal of Operations and Production Management*, 25, pp. 815–823 (2007).

[37] Martinez-Costa, M., Martinez-Lorente, A.R. and Choi, T.Y. "Simultaneous consideration of TQM and ISO 9000 on performance and motivation: an empirical study of Spanish companies", *International Journal of Production Economics*, 113, pp. 23–39 (2008).

[38] Karamouz, M., Ahmadi, A. and Nazif, S. "Development of management schemes in irrigation planning: economic and crop pattern consideration", *Scientia Iranica, Transactions A: Civil Engineering*, 16(6), pp. 457–466 (2009).

[39] Mostaghel, R. and Albadvi, A. "A cross-cultural comparison of service quality prioritization", *Scientia Iranica, Transactions E: Industrial Engineering*, 16(1), pp. 65–72 (2009).

[40] Fok, L.Y., Hartman, S.J., Patti, A.L. and Razek, J.R. "Human factors affecting the acceptance of total quality management", *International Journal of Quality & Reliability Management*, 17(7), pp. 714–729 (2000).

[41] Neely, A., Gregory, M. and Platts, K. "Performance measurement system design—a literature review and research agenda", *International Journal of Operations and Production Management*, 15(4), pp. 80–116 (1995).

[42] Neely, A., Gregory, M. and Platts, K. "Performance measurement system design—a literature review and research agenda", *International Journal of Operations and Production Management*, 25(12), pp. 1228–1263 (2005).

[43] Phusavat, K., Anussornnitisarn, P., Helo, P. and Dwight, R. "Performance measurement: roles and challenges", *Industrial Management + Data Systems*, 109(5), pp. 646–664 (2009).

[44] Phusavat, K. and Photaranon, W. "Productivity/performance measurement, case application at the government pharmaceutical organization", *Industrial Management + Data Systems*, 106(9), pp. 1271–1287 (2006).

[45] Kulmala, H.I., Ahoniemi, L. and Nissinen, V. "Performance through measuring leader's profiles: an empirical study", *International Journal of Production Economics*, 122, pp. 385–394 (2009).

[46] Johnston, R. and Pongatichat, P. "Managing the tension between performance measurement and strategy: coping strategies", *International Journal of Operations and Production Management*, 28(10), pp. 941–967 (2008).

[47] Marchand, M. and Raymond, L. "Researching performance measurement systems—an information systems perspective", *International Journal of Operations and Production Management*, 28(7), pp. 663–686 (2008).

[48] Garengo, P. and Bititci, U. "Towards a contingency approach to performance measurement: an empirical study in Scottish SMEs", *International Journal of Operations and Production Management*, 27(8), pp. 802–825 (2007).
[49] Ukko, J., Tenhunen, J. and Rantanen, H. "Performance measurement impacts on management and leadership: perspectives of management and employees", *International Journal of Production Economics*, 110, pp. 39–51 (2007).
[50] Bititci, U.S., Mendibil, K., Nudurupati, S., Garengo, P. and Turner, T. "Dynamics of performance measurement and organizational culture", *International Journal of Operations and Production Management*, 26(12), pp. 1325–1350 (2006).
[51] Neely, A. "The evolution of performance measurement research—developments in the last decade and a research agenda for the next", *International Journal of Operations and Production Management*, 25(12), pp. 1264–1277 (2005).
[52] Bititci, U.S., Mendibil, K., Martinez, V. and Albores, P. "Measuring and managing performance in extended enterprises", *International Journal of Operations and Production Management*, 25(4), pp. 333–353 (2005).
[53] Evans, J.R. "An exploratory study of performance measurement systems and relationships with performance results", *Journal of Operations Management*, 22, pp. 219–232 (2004).
[54] Bititci, U.S., Nudurupati, S.S., Turner, T.J. and Creighton, S. "Web enabled performance measurement systems—management implications", *International Journal of Operations and Production Management*, 22(11), pp. 1273–1287 (2002).
[55] Kennerley, M. and Neely, A. "A framework of the factors affecting the evolution of performance measurement systems", *International Journal of Operations and Production Management*, 22(11), pp. 1222–1245 (2002).
[56] Bourne, M., Mills, J., Wilcox, M., Neely, A. and Platts, K. "Designing, implementing and updating performance measurement systems", *International Journal of Operations and Production Management*, 20(7), pp. 754–771 (2000).
[57] Neely, A., Mills, J., Platts, K., Richards, H., Gregory, M., Bourne, M. and Kennerley, M. "Performance measurement system design: developing and testing a process-based approach", *International Journal of Operations and Production Management*, 20(10), pp. 1119–1145 (2000).
[58] Green Jr., K.W., Medlin, B. and Whitten, D. "Developing optimism to improve performance: an approach for the manufacturing sector", *Industrial Management + Data Systems*, 104(2), pp. 106–114 (2004).
[59] Medlin, B. and Green Jr., K.W. "Enhancing performance through goal setting, engagement, and optimism", *Industrial Management + Data Systems*, 109(7), pp. 943–956 (2009).
[60] Tarng, M.Y. and Liu, H.Y. "Creating a document management system", *Industrial Management + Data Systems*, 94(9), pp. 9–15 (1994).
[61] Laitinen, E.K. "Importance of performance information in managerial work", *Industrial Management + Data Systems*, 109(4), pp. 550–569 (2009).
[62] Ojiako, U., Johansen, E. and Greenwood, D. "A qualitative re-construction of project measurement criteria", *Industrial Management + Data Systems*, 108(3), pp. 405–417 (2008).
[63] Ahmad, S. and Schroeder, R.G. "The impact of human resource management practices on operational performance: recognizing country and industry differences", *Journal of Operations Management*, 21, pp. 19–43 (2003).
[64] Nahm, A.Y., Vonderembse, M.A. and Koufteros, X.A. "The impact of organizational structure on time-based manufacturing and plant performance", *Journal of Operations Management*, 21, pp. 281–306 (2003).
[65] De Toni, A. and Tonchia, S. "Performance measurement systems—models, characteristics and measures", *International Journal of Operations and Production Management*, 21(1–2), pp. 46–70 (2001).
[66] Najmi, M. and Kehoe, D.F. "The role of performance measurement systems in promoting quality development beyond ISO 9000", *International Journal of Operations and Production Management*, 21(1–2), pp. 159–172 (2001).
[67] Jayaram, J., Droge, C. and Vickery, S.K. "The impact of human resource management practices on manufacturing performance", *Journal of Operations Management*, 18, pp. 1–20 (1999).
[68] Bose, R. "Understanding management data systems for enterprise performance management", *Industrial Management + Data Systems*, 106(1), pp. 43–59 (2006).
[69] March, S.T. and Hevner, A.R. "Integrated decision support systems: a data warehousing perspective", *Decision Support Systems*, 43, pp. 1031–1043 (2007).
[70] Marakas, G.M., *Systems Analysis & Design—an Active Approach*, 2nd ed., McGraw-Hill, USA (2006).
[71] Golnabi, H., Azimi, P. and Poseh, G.H. "Data acquisition and resistance measurements using a simple program", *Scientia Iranica*, 14(5), pp. 467–473 (2007).
[72] Hedelin, L. and Allwood, C.M. "IT and strategic decision making", *Industrial Management + Data Systems*, 102(2), pp. 125–139 (2002).
[73] Jarke, M., Lenzerini, M., Vassiliou, Y. and Vassiliadis, P., *Fundamentals of Data Warehouses*, Springer, Cambridge, MA (2000).
[74] Lau, H.C.W., Chan, F.T.S., Fung, R. and Wong, C.W.Y. "An XML-based real-time quality measurement scheme", *Industrial Management + Data Systems*, 104(6), pp. 505–512 (2004).
[75] Lee, S.M. and Hong, S. "An enterprise-wide knowledge management system infrastructure", *Industrial Management + Data Systems*, 102(1), pp. 17–25 (2002).
[76] Ahmad, I., Azhar, S. and Lukauskis, P. "Development of a decision support system using data warehousing to assist builders/developers in site selection", *Automation in Construction*, 13, pp. 525–542 (2004).
[77] Zhiliang, M., Wong, K.D., Heng, L. and Jun, Y. "Utilizing exchanged documents in construction projects for decision support based on data warehousing techniques", *Automation in Construction*, 14, pp. 405–412 (2005).
[78] Moon, S.W., Kim, J.S. and Kwon, K.N. "Effectiveness of OLAP-based cost data management in construction cost estimate", *Automation in Construction*, 16, pp. 336–344 (2007).
[79] Forcada, N., Casals, M., Roca, X. and Gangolells, M. "Adoption of web databases for document management in SMEs of the construction sector in Spain", *Automation in Construction*, 16, pp. 411–424 (2007).
[80] Ang, J. and Teo, T.S.H. "Management issues in data warehousing: insights form the housing and development board", *Decision Support Systems*, 29, pp. 11–20 (2000).
[81] Lair, R., *Beginning Silverlight 2*, A Press, New York, USA (2008).
[82] Anumba, C.J., Baugh, C. and Khalfan, M.M.A. "Organizational structures to support concurrent engineering in construction", *Industrial Management + Data Systems*, 102(5), pp. 260–270 (2002).
[83] Pinto, J.K., *Project Management. Achieving Competitive Advantage*, Pearson Educations International, New Jersey, USA (2007).
[84] Zegordi, S.H. and Nahavandi, N. "Measuring productivity indexes and efficiency in the container terminal at port Rajaei", *Scientia Iranica*, 9(3), pp. 248–254 (2002).
[85] Hoehn, W. "Managing organizational performance: linking the balanced scorecard to a process improvement technique", *Proc. 4th Ann. Int. Symp. Ind. Eng. Per. Manag.* Kasetsart University, Bangkok, pp. 1–12 (2003).
[86] Hanna, V., Burns, N.D. and Backhouse, C.J. "Realigning organizational variables to support workplace behaviour", *International Journal of Operations and Production Management*, 20(12), pp. 1380–1391 (2000).
[87] Kuwaiti, M.E. "Performance measurement process: definition and ownership", *International Journal of Operations and Production Management*, 24(1), pp. 55–78 (2004).
[88] Kutucuoglu, K.Y., Hamali, J., Irani, Z. and Sharp, J.M. "A framework for managing maintenance using performance measurement systems", *International Journal of Operations and Production Management*, 21(1–2), pp. 173–194 (2001).
[89] Laitinen, E.K., Lansiluoto, A. and Rautiainen, I. "Extracting appropriate scope for information systems: a case study", *Industrial Management + Data Systems*, 109(3), pp. 305–321 (2009).
[90] Palvia, S.C., Sharma, R.S. and Conrath, D.W. "A socio-technical framework for quality assessment of computer information systems", *Industrial Management + Data Systems*, 101(5), pp. 237–251 (2001).

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